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VULNERABILITY OF BUILDINGS, URBAN INFRASTRUCTURE AND SYSTEMS: THE CASE OF MT. ETNA

Fabrizio MERONI[1], Gaetano ZONNO[2] and Salvatore D'AMICO[3]

Natural disasters, such as earthquakes and volcanoes, have strong effects on the socio-economic wellbeing of countries and their people. The consequences of these events can lead to complex cascades of related incidents; when these expand across sectors and borders, and in more serious contexts, they can threaten our basic survivability. These events have clearly demonstrated that preparedness and disaster management is a dynamic process that requires a holistic analysis of critical interdependencies among core infrastructures.
In this context of complexity, uncertainty and doubt, the Disruption Index (DI) proposed in the framework of the UPStrat-MAFA project aims to improve our understanding of earthquake and volcano hazards and their impacts. Several guiding principles and methods have been developed to serve as the basis to measure the different earthquake impacts, with analysis and discussion of the data that provide clearer pictures of how the systems and the disruption of their functionality affect an urban area. The main concepts that explain the DI can be found in Ferreira et al. (2014). Constructing the DI requires good quality information about the physical, spatial and vulnerability conditions of the study area; this means the information that reflects the full knowledge of the true situation.

The information on vulnerability is an element that together with shaking ground-motion parameters, will be used for the identification of risk. Some studies about measures of vulnerability have already been developed, like simulators, vulnerability assessment of buildings, non-structural components, critical assets, lifeline (critical) infrastructures, and others.
The study of the seismic vulnerability of an urban region follows two main steps: (i) exposure geo-referenced inventory and vulnerability classification of assets at risk; and (ii) vulnerability characterisation according to damage models. In the UPStrat-MAFA project, damage models are selected in agreement with the macroseismic evaluation of the seismic hazard provided in the project, so a macroseismic method for the vulnerability assessment of buildings should be adopted. The damage model proposed by Lagomarsino and Giovinazzi (2006) was successfully applied in previous seismic risk studies (as in the EU LessLoss project, see Spence, 2007). This model classifies the building stock according to the vulnerability table of the European Macroseismic Scale (EMS 98) (Grünthal, 1998), and predicts damage distributions, conditioned by an intensity level, for each damage grade of EMS-98. According to Lagomarsino and Giovinazzi (2006), the seismic vulnerability of the elements at risk that belong to any given building typology (i.e., buildings with a similar behaviour during an earthquake) is described by a probable vulnerability index, which varys between 0 and 1, and is independent from the hazard severity level. This vulnerability index can be increased or decreased by a group of behaviour modifiers, like, for instance, state of conservation, or the asymmetry, of a building. The average vulnerability for a region is obtained by weighting the typology vulnerability index by the exposure of the several typologies in a region.

[1] Dr, INGV, Milano, fabrizio.meroni@mi.ingv.it
[2] Dr, INGV, Milano, gaetano.zonno@mi.ingv.it
[3] Dr, INGV, Catania, salvatore.damico@ct.ingv.it

The Mt. Etna area is highly urbanised, with many villages located all around the volcano at different altitudes of up to 700 m a.s.l.. In particular, the southern and eastern flanks are the most populated areas, where the villages are very close to each other. Moreover, there is a dense network of roads, power lines and methane pipelines that connects the villages, roads and railways along the coast. The study area covers part of the south-eastern flank of the volcano, over an area of approximately 510 square kilometres, and covering 28 municipalities. Using a Geographic Information System we have stored a huge quantity of data that was collected by the local Civil Defence Protection as part of socially useful work - LSU (Cherubini, 1999), to compute the risk maps for Mt. Etna in recent years. Data includes the electricity systems (e.g. transformation stations), transport (e.g. bridges, roads, tunnels), the water supply systems (e.g. pumping stations, water treatment plants) and the sewage systems (e.g. pumping stations, treatment plants) and natural gas systems (gas pressure reduction and measurement stations.). For the sites where the information about the seismic vulnerability is not available, we have estimated here the vulnerability from other information, such as the age, material and size of the object.

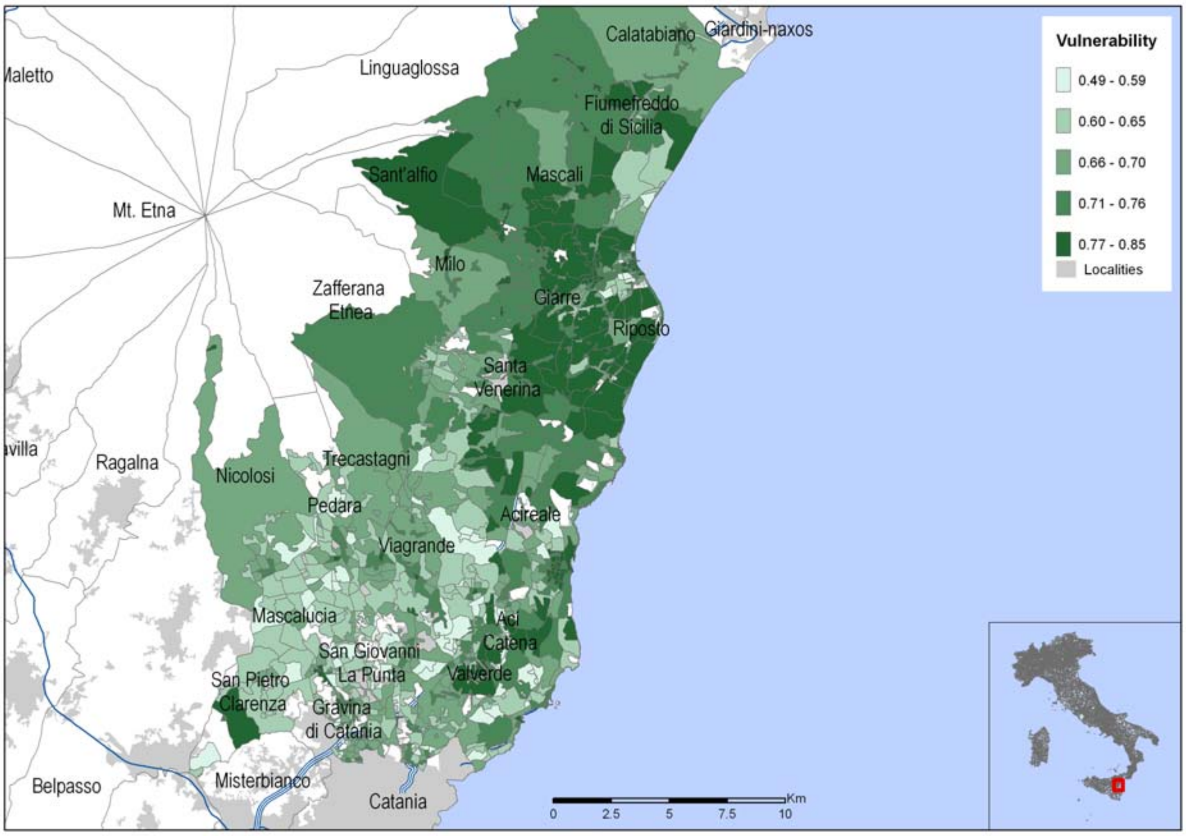

Figure 1. Vulnerability map of residential buildings in the Mt. Etna area.

A synthetic vulnerability index was introduced (figure 1) to show and compare the vulnerabilities of the residential buildings for different census sections. This is defined by the weighted sum of the volumes for each vulnerability class, multiplied by the score of each vulnerability class. We highlight that while for the residential buildings the maps provide information in terms of census sections, for all of the other elements, the information is provided in terms of units, e.g., schools. The physical structures exposed to earthquake impact considered in this case study are: residential buildings, primary and secondary schools, security buildings (i.e., police and fire stations, and military structures), healthcare buildings, highway bridges, elements of the natural gas system (i.e., pipelines, gas pressure reduction, measurement stations), electricity power stations (and local electricity transformers), water and wastewater pipelines, explosives and inflammable liquid tanks. Each of the types of the physical structures exposed to the earthquake impact taken into account can suffer different levels of damage severity; for buildings, damage severity is classified in 5 levels, for all the other elements, there are 4 levels of severity. For the description of the severity levels, e.g., for electric power stations level 2 can be described as “reduced power flow and operational without repair”, whereas level 3 indicates “no power available, but operational after repair.” For all of the elements, 1 indicates negligible impact, whereas the maximum level (4 or 5) indicates destruction/ collapse.

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